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BOLT TORQUE TESTS IN VACUUM

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16. ABSTRACT

A report on test equipment and tests made to determine the effects of a vacuum environment on the release torque of various threaded fastener materials both lubricated and unlubricated. Results show the lowest release torques were obtained with steel bolts using an inorganically bonded dry film lubricant in vacuum while the highest release torques occurred with unlubricated steel fasteners in air.

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BOLT TORQUE TESTS IN VACUUM

INTRODUCTION

A series of tests were made in air and vacuum to determine the effect of the vacuum environment on the release torque of various threaded fastener materials both lubricated and unlubricated. In general, the lowest release torques were obtained with steel bolts using an inorganically bonded dry film lubricant in vacuum while the highest release torques occurred with unlubricated steel fasteners in air.

DESCRIPTION

Test Equipment

The test mechanism used for these evaluations is shown schematically in Figure 1. The testing was done in an ion pump vacuum system capable of pressures in the range of 10^{-6} to 10^{-7} torr with the test equipment operating. Test specimens consisted of bolts and tapped plates of various metals. The tapped plates were supported in a ball bearing mounted holder and restrained from rotating by a load cell so that any torques imposed on the tapped plate could be recorded on a Sanborn recorder. The machine screw was driven through a speed reducer from the outside of the chamber using a magnetic coupling.

During test the machine screw was threaded into the tapped plate and tightened to 60 pound-feet torque. The test was then allowed to remain in the torqued condition for 15 minutes after which it was released and recordings were made on the torque required to release the bolts. This procedure was repeated 8 times for each test to provide an average release torque value. One-half inch No. 20 NC-2 bolts of aluminum, stainless steel, and mild steel were selected for test with various combinations of the same materials for the tapped plates. The lubricants selected for test were FS 1281 a widely used fluorosilicone lubricant manufactured by Dow Corning and MLF-5 a sodium silicate bonded dry film lubricant containing MoS_2, graphite and gold powder. Table I gives the various combinations evaluated during this program.

TABLE I. VARIOUS METAL COMBINATIONS EVALUATED

Bolt Material	Plate Material	Air (Tests No.)			Vacuum (Tests No.)		
		No Lube	FS 1281	MLF-5	No Lube	FS 1281	MLF-5
Mild Steel	Mild Steel	17, 18, 13, 14	1, 2	28	43, 47		36, 38 xx
Mild Steel	Aluminum		5, 6	25			31, 39
Mild Steel	Stainless Steel	16, 15	3, 4	30	45*		37, 33 xx
Stainless Steel	Stainless Steel	23, 24*	7, 8	29	46*		34, 42
Stainless Steel	Aluminum	19, 20	12, 11	26	44*		32, 40
Stainless Steel	Mild Steel	22, 21*	9, 10	27	48*		35, 41

* Threads galled before end of test.
xx No Test. Over torqued and threads stripped.

Tests

Table II shows the material combinations tested and numbers each combination. These numbers will be used in the remainder of this report to identify various bolt and tapped plate combinations.

TABLE II. MATERIAL COMBINATIONS

Combination Number	Machine Screw Material	Plate Material
1	Stainless Steel	Mild Steel
2	Stainless Steel	Aluminum
3	Stainless Steel	Stainless Steel
4	Mild Steel	Stainless Steel
5	Mild Steel	Aluminum
6	Mild Steel	Mild Steel

The first series of tests were made on unlubricated bolts and plates in air. Results of these evaluations are shown in Figure 2. The highest release torques under these conditions were obtained with mild steel-stainless steel combinations. The same combinations were then tested in vacuum giving the results shown in Figure 3. Under these conditions only the stainless steel-aluminum combination showed significantly higher release torque; however, all combinations, except the mild steel-mild steel, showed some thread galling at the completion of the test.

A third series of tests were made in air using a fluorosilicone grease (FS 1281) as a thread lubricant. Results of these tests are shown in Figure 4. It appears that the grease provides a more constant release torque with all material combinations than was exhibited by the unlubricated fasteners. The average release torque for the grease lubricated fasteners remained high; averaging within 7 or 8 pound-feet of the applied torque. No tests of the grease lubrication were made under vacuum conditions because of the danger of contaminating the ion pumps. At ambient temperature the vacuum should have little effect on the fluorosilicone lubricant.

The final tests were made using a bonded dry film lubricant (MLF-5) applied to the bolt threads only. Results of the atmospheric tests are shown in Figure 5. These results show a considerable drop in the torque required to release the bolts over the unlubricated and grease lubricated specimens. Results of the final tests using the bonded dry lubricant in vacuum are shown in Figure 6. Again there is a rather dramatic decrease in the release torque required which now ranges to about 1/2 of the applied torque. Both specimen sets which had one aluminum component showed release torques about 70% higher than those sets which had both components made of harder materials. Average release torques for all tests are shown in Figure 7.

CONCLUSIONS

The results of tests conducted under this program suggest the following conclusions:

1. Bolt release torque or friction is a function of substrate material, the lubricant and the environment.

2. The maximum release torque of unlubricated bolts in air and in vacuum does not vary widely; however, galling is more apt to occur in vacuum than under normal atmospheric conditions.

3. A fluorosilicone grease provides only slightly lower release torques than the same bolts unlubricated; however, the bolt torques are more consistent despite material differences than the unlubricated specimens.

4. Molybdenum disulfide base dry lubricants provide low release torques for all material combinations in air and are especially effective in vacuum.

5. Dry film lubricants are more effective on hard surfaces in contact with hard surfaces than when one or both surfaces are relatively soft.

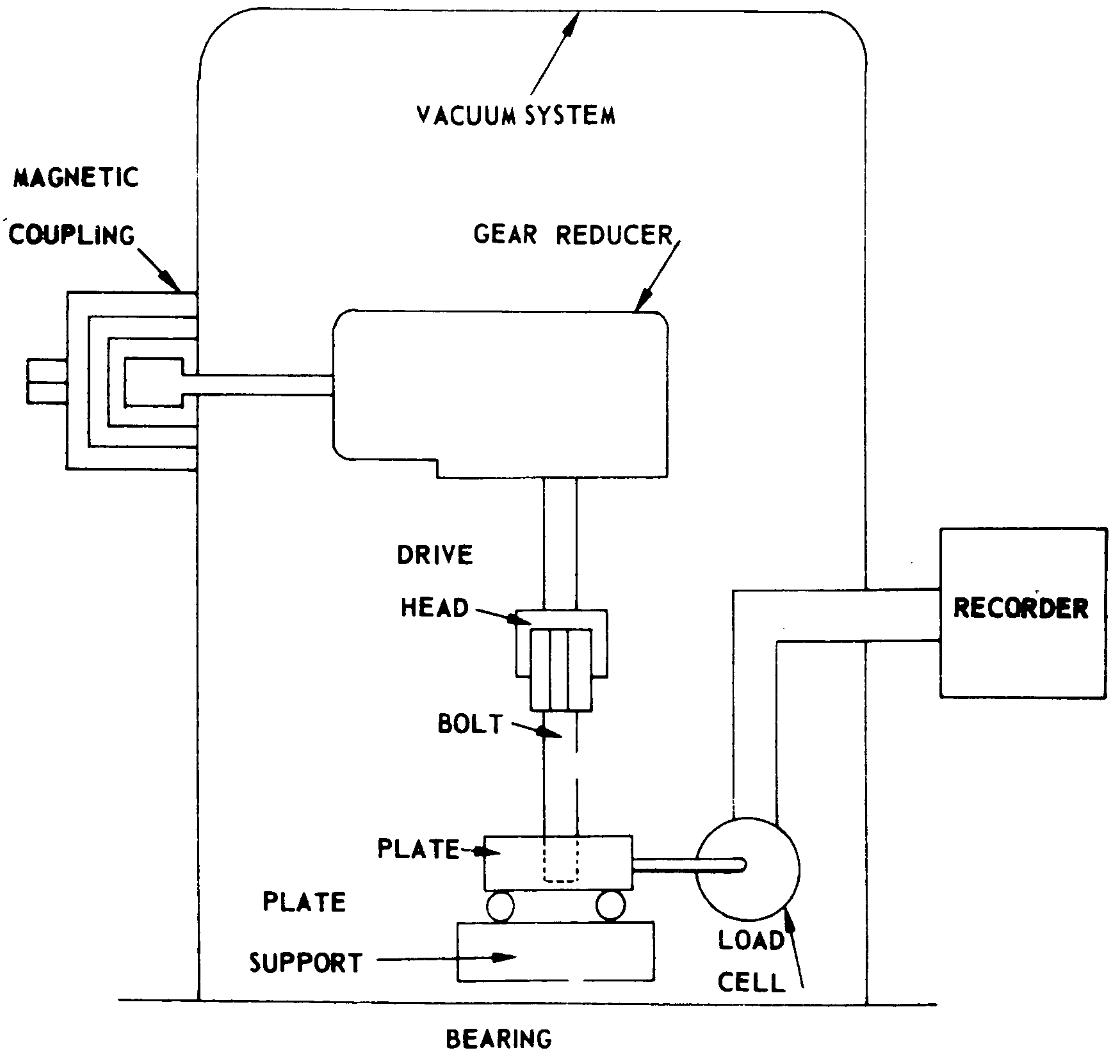

Figure 1. Bolt torque test schematic.

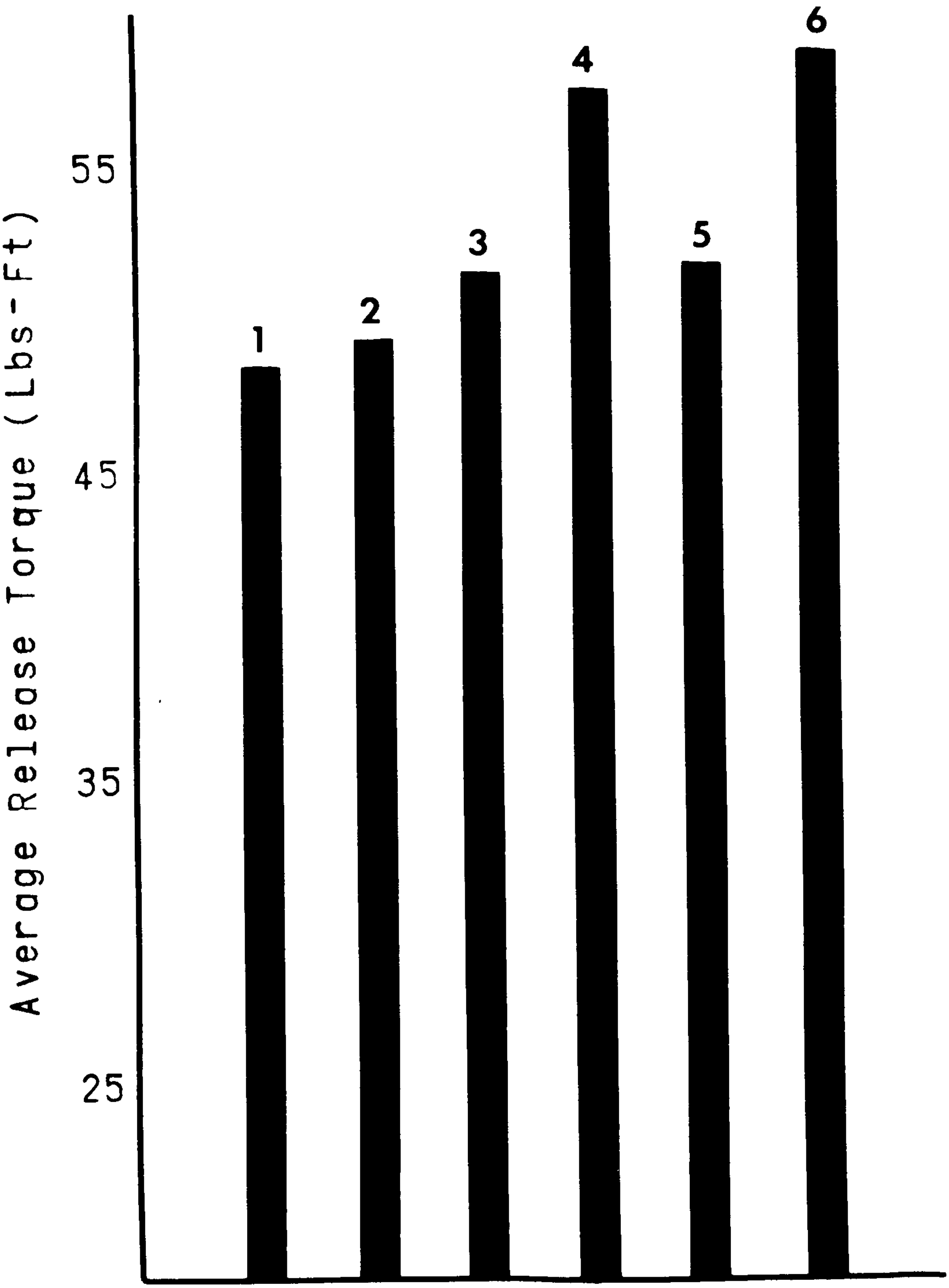

Figure 2. Metal fasteners with no lubricant tested in air.

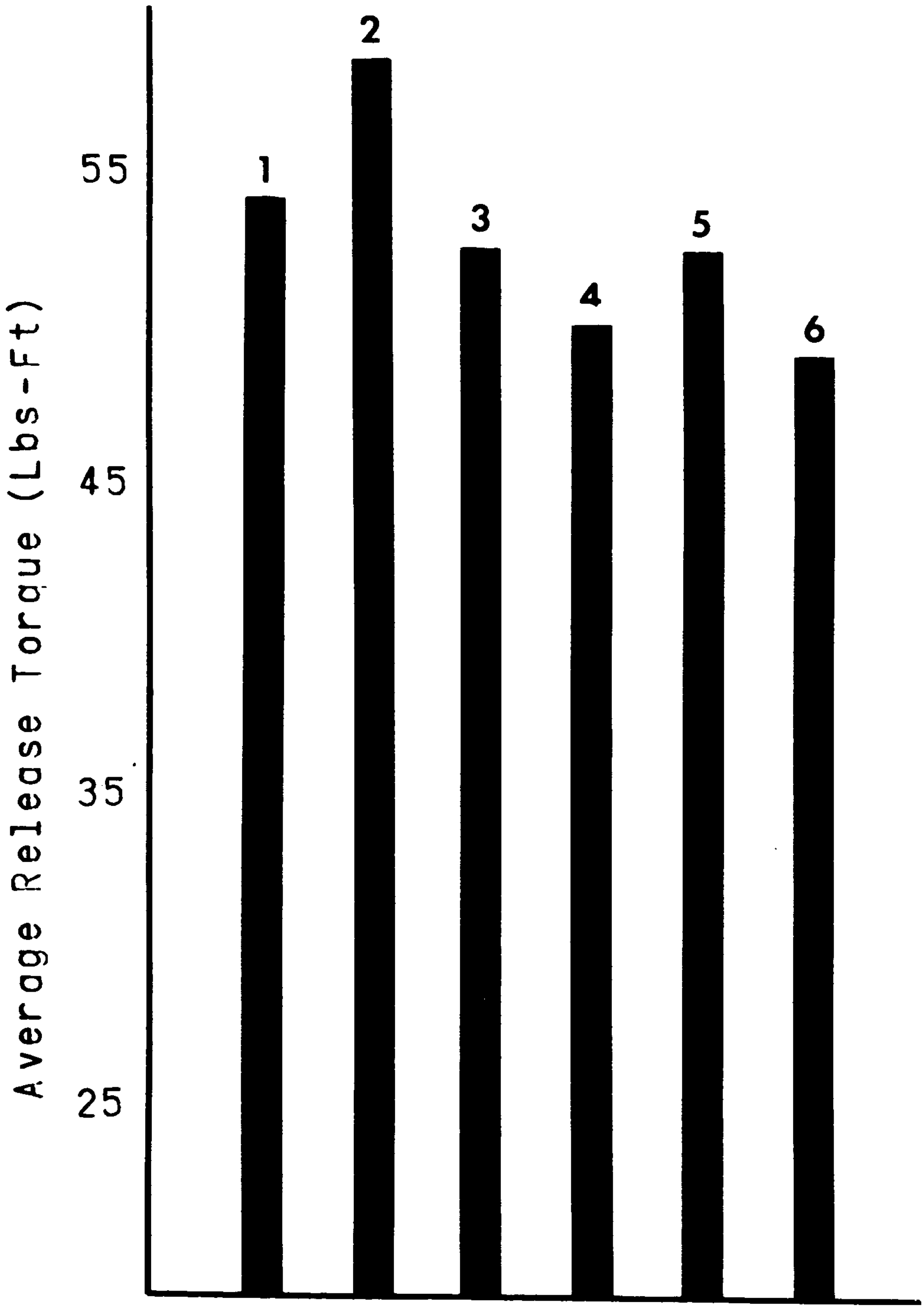

Figure 3. Metal fasteners with no lubricant tested in vacuum.

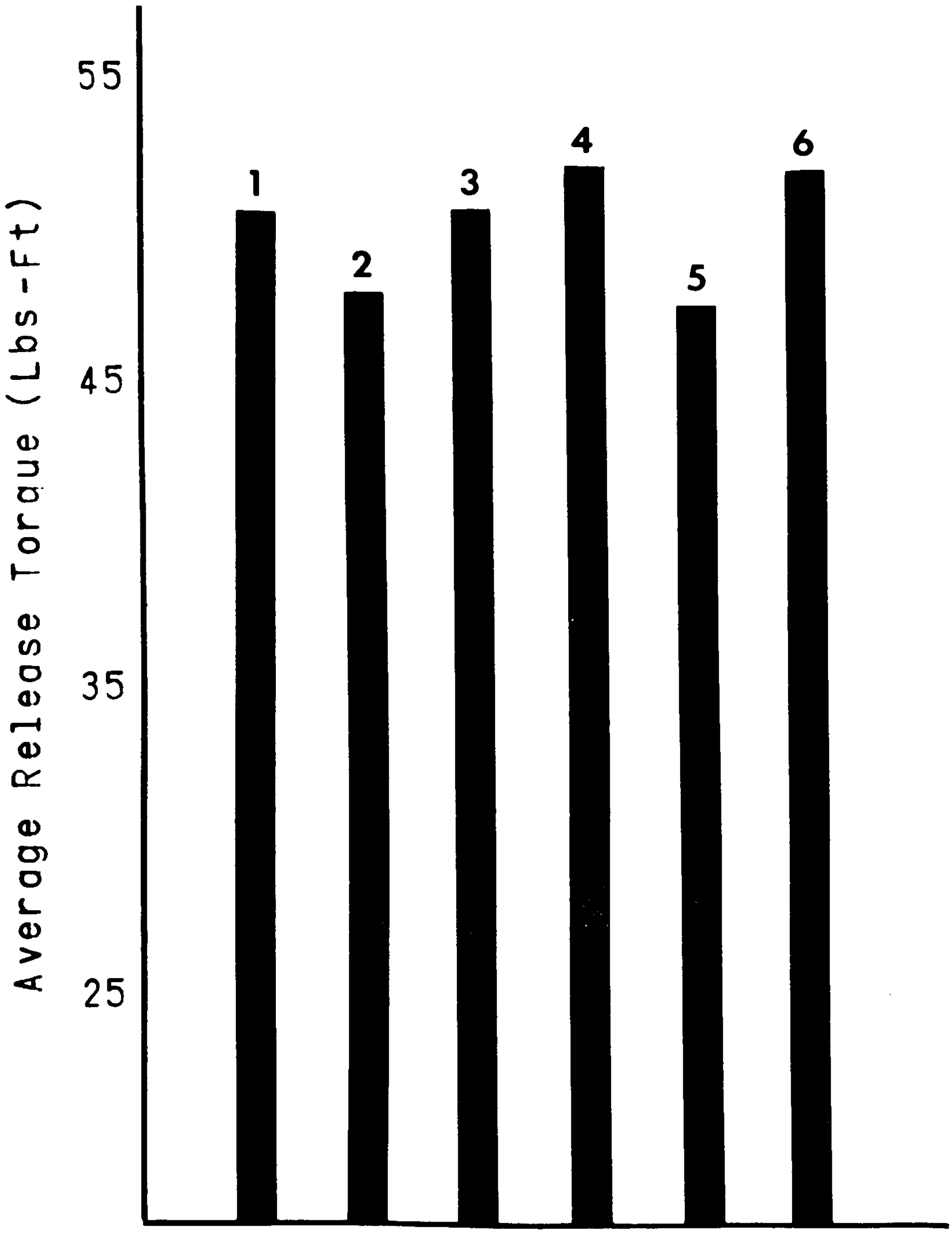

Figure 4. Metal fasteners lubricated with FS 1281 and tested in air.

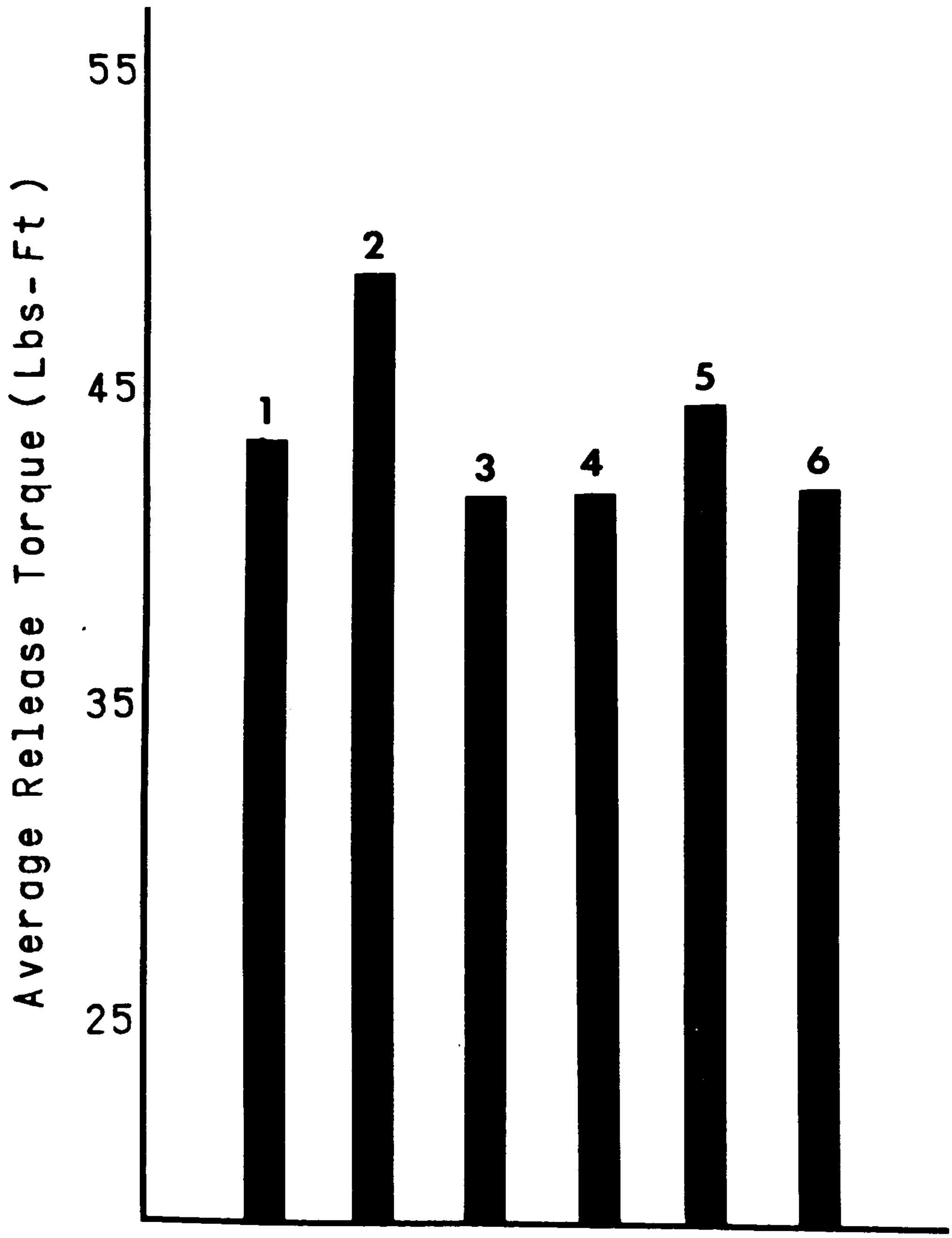

Figure 5. Metal fasteners lubricated with MLF-5 and tested in air.

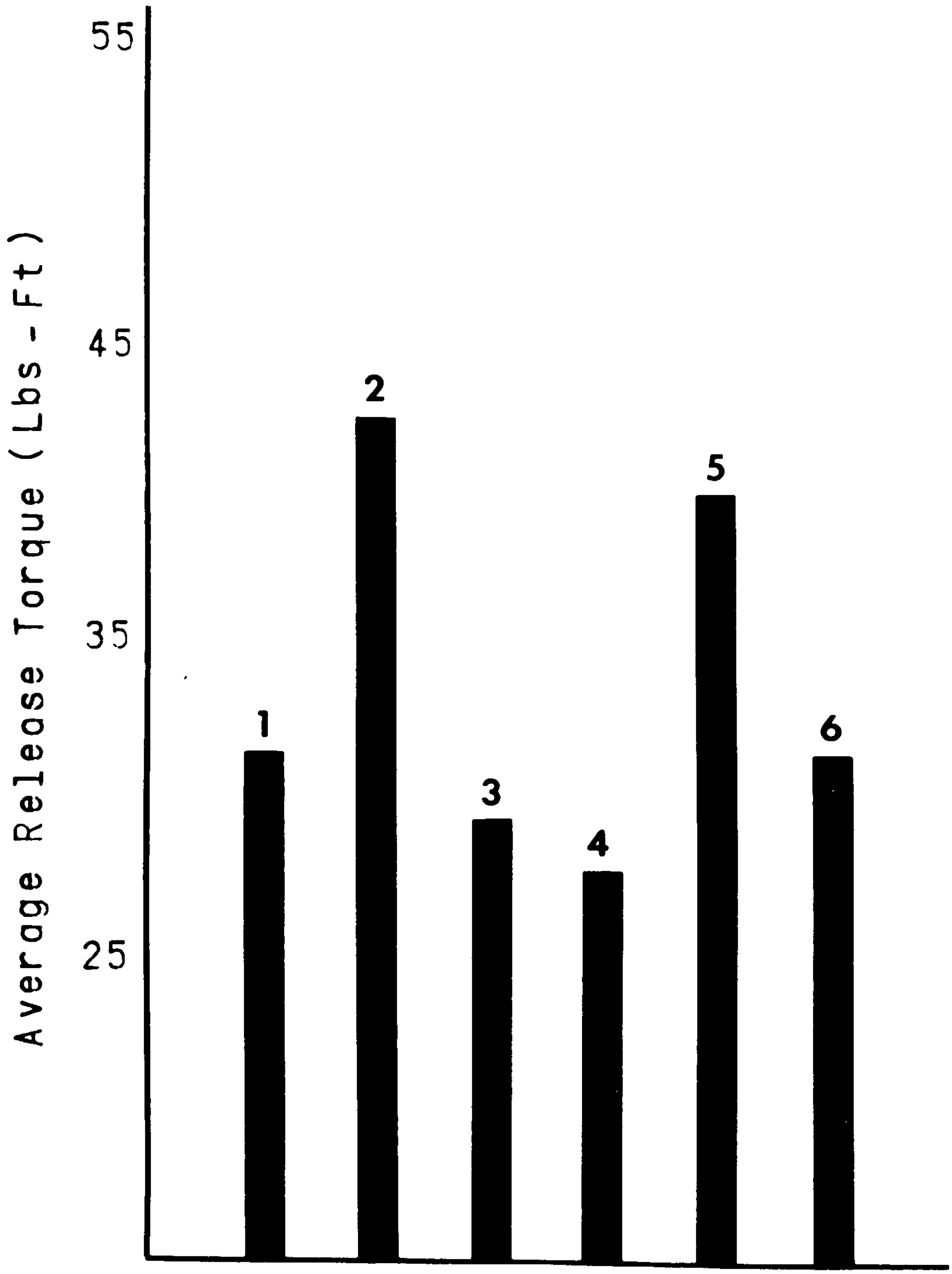

Figure 6. Metal fasteners lubricated with MLF-5 and tested in vacuum.

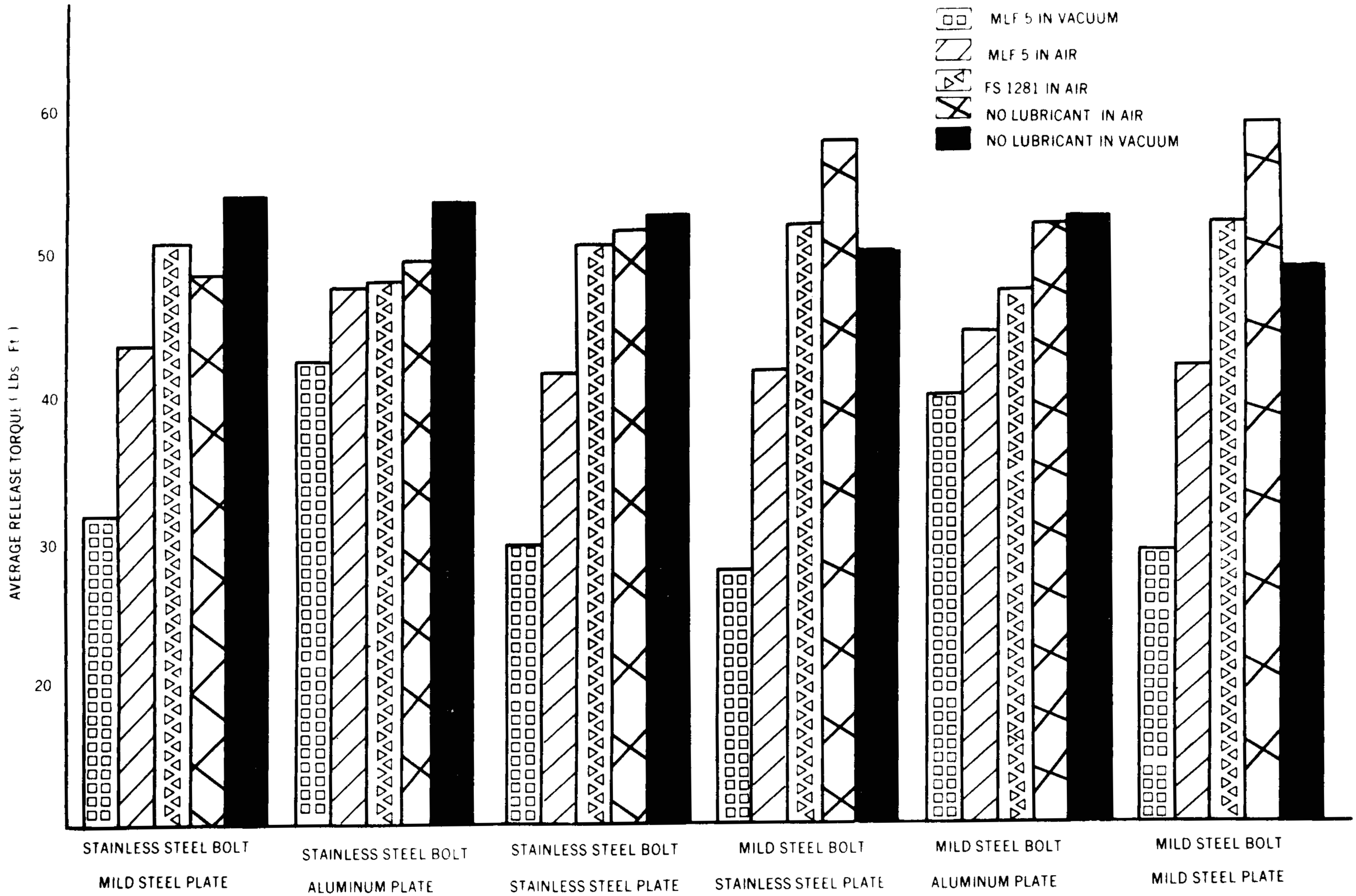

Figure 7. Average release torques for all tests.

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APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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